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This report is a revised version of a previous document prepared by MRI for EPA entitled "Emission Factor Development for the Feed and Grain Industry" (EPA-450/3-75-054) dated October 1974. The subject of this report is emission factors for grain elevators and other feed and grain operations (excluding alfalfa dehydration).

Major portions of the information and data presented in this report are the same as that in the previous document. The primary difference is the revision of some data for country elevators based on recent EPA tests conducted at two elevators in Kansas, and other reports made available through the North Dakota State Department of Health. To our knowledge, no other new information or data have become available for reevaluation of emission factors for the subject sources in the feed and grain industry.

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SOURCE TEST EVALUATION FOR FEED AND GRAIN INDUSTRY

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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SOURCE TEST EVALUATION FOR FEED AND GRAIN INDUSTRY

by

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Publication No. EPA-450/3-76-043

PREFACE

This report was prepared for the Environmental Protection Agency (EPA) under Contract No. 68-02-1403 (Task 28). The primary purpose of the work was to evaluate emission test data for country elevators in order to revise and update previous work done by Midwest Research Institute (MRI) for EPA that was contained in the EPA Publication No. EPA-450/3-75-054 entitled "Emission Factor Development for the Feed and Grain Industry." The country elevator test data that were evaluated consisted of recent tests conducted by MRI for EPA at two elevators in Kansas and other test reports at elevators in North Dakota that were supplied by Mr. Dana Mount of the North Dakota State Department of Health. Mr. Mount's assistance in this and previous work is gratefully acknowledged.

This report was written by Mr. M. P. Schrag, Head, Environmental Systems Section, and Mr. P. G. Gorman with the assistance of Mr. W. H. Maxwell.

Approved for:

MIDWEST RESEARCH INSTITUTE

L. J. Shannon

L. J. Shannon, Director
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Sciences Division

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INTRODUCTION

This task report is a revised version of a previous document prepared by MRI for EPA entitled "Emission Factor Development for the Feed and Grain Industry" (EPA-450/3-75-054) dated October 1974. The subject of this report is emission factors for grain elevators and other feed and grain operations (excluding alfalfa dehydration). Consistent with the previous report, this report is arranged as follows:

Emissions and Controls

- Grain Elevators
- Grain Processing Operations

Background and Support Information for Emission Factors for Feed and Grain Mills and Elevators

- Grain Elevators
- Grain Processing Operations

Major portions of the information and data presented in this report are the same as that in the previous document. The primary difference is the revision of some data for country elevators based on recent EPA tests conducted at two elevators in Kansas, and other reports made available through the North Dakota State Department of Health. To our knowledge, no other new information or data have become available for reevaluation of emission factors for the subject sources in the feed and grain industry.

FEED AND GRAIN MILLS AND ELEVATORS

EMISSION FACTORS

General

Grain elevators are transfer and storage areas for grain and are usually classified as either country, terminal, or export elevators. Country elevators generally receive grains as they are harvested from fields within a 10- to 20-mile radius of the elevator. The country elevators unload, weigh and store grain as it is received from the farmer. In addition, the country elevator may dry or clean the grain before it is shipped to the terminal elevators or processors.

Terminal elevators receive most of their grain from country elevators and ship to processors, other terminals, and exporters. The primary function of a terminal elevator is to store grain in quantity without deterioration and to bring it to commercial grade so as to conform to the needs of buyers. As with country elevators, terminals dry, clean and sort grain. In addition, they can blend grain to meet buyer specifications.

Export elevators are similar to terminal elevators with the exception that they mainly load grain on ships for export.

The other types of operations involved in the processing of grain, in grain and feed plants, range from very simple mixing steps to complex processes which are characteristic of industrial processing plants. Included are such diverse processes as: (a) simple mixing processes in feed mills, (b) grain milling in flour mills, (c) solvent extracting in soybean processing plants, and (d) a complex series of processing steps in a corn wet-milling plant.

Emissions and Controls

Grain handling, milling and processing include a variety of operations from the initial receipt of the grain at either a country or terminal elevator to the delivery of a finished product. Flour, livestock feed, soybean oil and corn syrup are among the products produced from plants in the grain and feed industry. Emissions from the feed and grain industry can be separated into two general areas, those occurring at grain elevators and those occurring at grain processing operations.

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Grain Elevators - Grain elevator emissions can occur from many different operations in the elevator including unloading (receiving), loading (shipping), drying, cleaning, headhouse (legs), tunnel belt, gallery belt and belt trippers. Emission factors for these operations at terminal, country and export elevators are presented in Table 1.

Most of the emission factors shown in Table 1 for terminal and export elevators are based on results reported in Ref. 1. Emission factors for drying were based on information in Refs. 2 and 3. For country elevators, the emission factors were based on the results in Ref. 1 and specific emission tests at country elevators (Refs. 4 to 9). All of these emission factors are approximate average values intended to reflect a variety of grain types. Actual emission factors for a specific source may be considerably different, depending on the type of grain, i.e., corn, soybeans, wheat, and other factors such as grain quality.

The emission factors shown in Table 1 represent the amount of dust generated per ton of grain processed through each of the designated operations (i.e., uncontrolled emission factors). Amounts of grain processed through each of these operations in a given elevator are dependent on such factors as the amount of grain turned (interbin transfer), amount dryed, and amount cleaned, etc. Because the amount of grain passing through each operation is often difficult to determine, it may be more useful to express the emission factors in terms of the amount of grain shipped or received, assuming these amounts are about the same over the long term. Emission factors from Table 1 have been modified accordingly and are shown in Table 2 along with the appropriate multiplier that was used as representative of typical ratios of throughput at each operation to the amount of grain shipped or received. This ratio is an approximate value based on average values for turning, cleaning, and drying in each type of elevator. However, operating practices in individual elevators are different, so these ratios, like the basic emission factors themselves, would be more valid for a group of elevators rather than individual elevators.

The factors in Tables 1 or 2 should not be added together in an attempt to obtain a single emission factor value for grain elevators because in most elevators some of the operations are equipped with control devices and some are not. Therefore, any estimation of emissions must be directed to each operation and its associated control device, rather than the elevator as a whole, unless the purpose was to estimate total potential (i.e., uncontrolled) emissions. An example of the use of emission factors in making an emission inventory is contained in Ref. 3.

Some of the operations listed in the tables, such as the tunnel belt and belt tripper, are internal or in-house dust sources which, if uncontrolled, might show lower than expected atmospheric emissions because of internal settling of dust. The reduction in emissions via internal settling

Table 1. PARTICULATE EMISSION FACTORS FOR GRAIN ELEVATORS[1-9]

Type of source	Emission factor (uncontrolled)[a] (lb/ton)	(kg/MT)
Terminal of elevators		
Unloaded (receiving)	1.00	0.50
Loading (shipping)	0.27	0.14
Removal from bins (tunnel belt)	1.40	0.70
Drying[b]	1.05	0.52
Cleaning[c]	3.00	1.50
Headhouse (legs)	1.50	0.75
Tripper (gallery belt)	1.00	0.50
Country elevators		
Unloading (receiving)	0.64	0.32
Loading (shipping)	0.27	0.13
Removal from bins	1.00	0.50
Drying[b]	0.68	0.34
Cleaning[c]	3.00	1.50
Headhouse (legs)	1.50	0.75
Export elevators		
Unloading (receiving)	1.00	0.50
Loading (shipping)	1.00	0.50
Removal from bins (tunnel belt)	1.40	0.70
Drying[b]	1.05	0.52
Cleaning[c]	3.00	1.50
Headhouse (legs)	1.50	0.75
Tripper (gallery belts)	1.00	0.50

a/ Emission factors are in terms of pounds of dust emitted per ton of grain processed by each source.

b/ Emission factors for drying are based on 1.8 lb/ton for rack dryers and 0.3 lb/ton for column dryers prorated on the basis of distribution of these two types of dryers in each elevator category, as discussed in Reference 3.

c/ Emission factor of 3.00 for cleaning is an average value which may range from < 0.50 for wheat up to 6.00 for corn.

Table 2. PARTICULATE EMISSION FACTORS FOR GRAIN ELEVATORS BASED ON AMOUNT OF GRAIN RECEIVED OR SHIPPED[a/]

Type of source	Emission factor lb/ton processed	×	Typical ratio of tons processed to tons received or shipped[d/]	=	Emission factor lb/ton received or shipped
Terminal elevators					
Unloading (receiving)	1.00		1.00		1.00
Loading (shipping)	0.27		1.00		0.27
Removal from bins (tunnel belt)	1.40		2.03		2.84
Drying[b/]	1.05		0.10		0.11
Cleaning[c/]	3.00		0.22		1.32
Headhouse (legs)	1.50		3.03		4.55
Tripper (gallery belt)	1.00		1.71		1.71
Country elevators					
Unloading (receiving)	0.64		1.00		0.64
Loading (shipping)	0.27		1.00		0.27
Removal from bins	1.00		2.08		2.91
Drying[b/]	0.68		0.25		0.17
Cleaning[c/]	3.00		0.08		0.48
Headhouse (legs)	1.50		3.08		4.62
Export elevators					
Unloading (receiving)	1.00		1.00		1.00
Loading (shipping)	1.00		1.00		1.00
Removal from bins (tunnel belt)	1.40		1.23		1.72
Drying[b/]	1.05		0.01		0.01
Cleaning[c/]	3.00		0.15		0.90
Headhouse (legs)	1.50		2.23		3.35
Tripper (gallery belt)	1.00		1.07		1.07

a/ Assumed that over the long term the amount received is approximately equal to amount shipped.
b/ See Note b/ in Table 1.
c/ See Note c/ in Table 1.
d/ Ratios shown are average values taken from a survey of many elevators across the U.S.[3/] These ratios can be considerably different for any individual elevator or group of elevators in the same locale.

is not known and it is quite possible that all of this dust is eventually emitted to the atmosphere due to subsequent external operations, internal ventilation or other means.

Many elevators utilize control devices on at least some sources. In the past, cyclones have commonly been applied to such sources as legs in the headhouse and tunnel belt hooding systems. More recently, fabric filters have been utilized at many elevators on almost all types of sources. However, some sources in grain elevators do present control problems. Control of loadout operations is one source that is difficult to control because of the problem of containment of the emissions. Probably the most difficult source to control, because of the large flow rate and high moisture content of the exhaust gases, is the dryers. Screen-houses or continuously vacuumed screen systems are available for reducing dryer emissions and have been applied at several facilities. Detailed descriptions of dust control systems for grain elevator operations and their estimated costs are contained in Ref. 2.

Grain Processing Operations - Grain processing operations include many of the operations performed in a grain elevator in addition to milling and processing of the grain. Emission factors for different grain milling and processing operations are presented in Table 3. Brief discussions of these different operations and the methods used for arriving at the emission factor values shown in Table 3 are presented below.

Emission factor data for feed mill operations are sparse. This is partly due to the fact that many ingredients, whole grain and other dusty materials (bran, dehydrated alfalfa, etc.), are received by both truck and rail and several unloading methods are employed. However, some operations (handling, shipping, and receiving) for a feed mill are similar to operations in a grain elevator, so an emission factor for each of these different operations was estimated on this basis. The remaining operations were estimated from the best information available.[2]

Three emission areas for wheat mill processing operations are grain receiving and handling, cleaning house, and milling operations. Data from a grain elevator study[1] were used to estimate emission factors for grain receiving and handling. Data for the cleaning house were insufficient to estimate an emission factor and information taken from Ref. 2 was used to estimate the emission factor for milling operations. The large emission factor for the milling operation is somewhat misleading because almost all of the sources involved are equipped with control devices to prevent product losses and fabric filters are widely used for this purpose.

Operations for durum mills and rye milling are similar to those of wheat milling. Therefore, most of these emission factors are equal to those for wheat mill operations.

Table 3. PARTICULATE EMISSION FACTORS FOR GRAIN PROCESSING OPERATIONS[1,2,3]

Type of source	Emission factor[a,b] (uncontrolled except where indicated) (lb/ton)	(kg/MT)
Feed mills		
Receiving	1.30	0.65
Shipping	0.50	0.25
Handling	3.00	1.50
Grinding	0.10[c]	0.05[c]
Pellet coolers	0.10[c]	0.05[c]
Wheat mills		
Receiving	1.00	0.50
Precleaning and handling	5.00	2.50
Cleaning house	-	-
Millhouse	70.00	35.00
Durum mills		
Receiving	1.00	0.50
Precleaning and handling	5.00	2.50
Cleaning house	-	-
Millhouse	-	-
Rye milling		
Receiving	1.00	0.50
Precleaning and handling	5.00	2.50
Cleaning house	-	-
Millhouse	70.00	35.00
Dry corn milling		
Receiving	1.00	0.50
Drying	0.50	0.25
Precleaning and handling	5.00	2.50
Cleaning house	6.00	3.00
Degerming and milling	-	-

Table 3. (Concluded)

Type of source	Emission factor[a,b] (uncontrolled except where indicated) (lb/ton)	(kg/MT)
Oat milling		
Total	2.50[d]	1.25[d]
Rice milling		
Receiving	0.64	0.32
Handling and precleaning	5.00	2.50
Drying	-	-
Cleaning and millhouse	-	-
Soybean mills		
Receiving	1.60	0.80
Handling	5.00	2.50
Cleaning	-	-
Drying	7.20	3.60
Cracking and dehulling	3.30	1.65
Hull grinding	2.00	1.00
Bean conditioning	0.10	0.05
Flaking	0.57	0.29
Meal dryer	1.50	0.75
Meal cooler	1.80	0.90
Bulk loading	0.27	0.14
Corn wet milling		
Receiving	1.00	0.50
Handling	5.00	2.50
Cleaning	6.00	3.00
Dryers	-	-
Bulk loading	-	-

a/ Emission factors are expressed in terms of pounds of dust emitted per ton of grain entering the plant (i.e., received), which is not necessarily the same as the amount of material processed by each operation.

b/ Blanks indicate insufficient information.

c/ Controlled emission factor (controlled with cyclones).

d/ Controlled emission factor (This represents several sources in one plant; some controlled with cyclones and others controlled with fabric filters.)

The grain unloading, handling and cleaning operations for dry corn milling are similar to those in other grain mills but the subsequent operations are somewhat different. Also, some drying of corn received at the mill may be necessary prior to storage. An estimate of the emission factor for drying was obtained from Ref. 2. Insufficient information was available to estimate emission factors for degerming and milling.

Information necessary to estimate emissions from oat milling was unavailable. It was also felt to be unwise to attempt to use emission factor data for other grains because handling of oats is reported to be dustier than many other grains. The only emissions factor data that were available were for controlled emissions.[2/] An overall controlled emission factor of 2.5 lb/ton was calculated from this data.

Emission factors for rice milling were based on those for similar operations in other grain handling facilities. Insufficient information was available to estimate emission factors for drying, cleaning and mill house operations.

Information taken from Ref. 2 was used to estimate emission factors for soybean mills.

Information on corn wet-milling emission factors was unavailable in most cases due to the wide variety of products and the diversity of operations. Receiving, handling and cleaning operations emission factors were assumed to be similar to those for dry corn milling.

Many of the operations performed in grain milling and processing plants are the same as those in grain elevators, so the control methods are similar. As in the case of grain elevators, these plants often use cyclones or fabric filters to control emissions from the grain handling operations (e.g., unloading, legs, cleaners, etc.). These same devices are also often used to control emissions from other processing operations and a good example of this is the extensive use of fabric filters in flour mills. However, there are also certain sources within some milling operations that are not amenable to use of these devices. Therefore, wet scrubbers have found some application, particularly where the effluent gas stream has high moisture content. Certain other sources have been found to be especially difficult to control, and one of these is the rotary dryers in wet corn mills. Descriptions of the emission control systems that have been applied to sources within the grain milling and processing industries are contained in Ref. 2.

BACKGROUND AND SUPPORT INFORMATION FOR EMISSION FACTORS FOR FEED AND GRAIN MILLS AND ELEVATORS

General

Grain elevators are transfer and storage areas for grain and are usually classified as either country, terminal, or export elevators. Country elevators generally receive grains as they are harvested from fields within a 10- to 20-mile radius of the elevator. The country elevators unload, weigh and store grain as it is received from the farmer. In addition, the country elevator may dry or clean the grain before it is shipped to the terminal elevators or processors.

Terminal elevators receive most of their grain from country elevators and ship to processors, other terminals, and exporters. The primary function of a terminal elevator is to store grain in quantity without deterioration and to bring it to commercial grade so as to conform to the needs of buyers. As with country elevators, terminals dry, clean and sort grain. In addition, they can blend grain to meet buyer specifications.

Export elevators are similar to terminal elevators with the exception that they mainly load grain on ships for export.

The other types of operations involved in the processing of grain, in grain and feed plants, range from very simple mixing steps to complex processes which are characteristic of industrial processing plants. Included are such diverse processes as: (a) simple mixing processes in feed mills, (b) grain milling in flour mills, (c) solvent extracting in soybean processing plants, and (d) a complex series of processing steps in a corn wet-milling plant.

Emissions and Controls

Grain handling, milling and processing include a variety of operations from the initial receipt of the grain at either a country or terminal elevator to the delivery of a finished product. Flour, livestock feed, soybean oil and corn syrup are among the products produced from plants in the grain and feed industry. Emissions from the feed and grain industry can be separated into two general areas, those occurring at grain elevators and those occurring at grain processing operations.

Grain Elevators - Grain elevator emissions can occur from many different operations in the elevator, including unloading (receiving), loading (shipping), drying, cleaning, headhouse (legs), tunnel belt, and belt trippers (primarily for terminal and export elevators). Emissions factors for several of these operations are presented in Table 4.

Table 4. PARTICULATE EMISSION FACTORS FOR GRAIN ELEVATORS

Type of source	Emission factor[a] (uncontrolled) lb/ton	kg/mg
Terminal elevators		
Unloading (receiving)	1.00[b]	0.50
Loading (shipping)	0.27[c]	0.14
Removal from bins (tunnel belt)	1.40[d]	0.70
Drying	1.05[e]	0.52
Cleaning	3.00[f]	1.50
Headhouse (legs)	1.50[g]	0.75
Tripper (gallery belt)	1.00[h]	0.50
Country elevators		
Unloading (receiving)	0.64[i]	0.32
Loading (shipping)	0.27[j]	0.13
Removal from bins (tunnel belt)	1.00[k]	0.50
Drying	0.68[l]	0.34
Cleaning	3.00[m]	1.50
Headhouse (legs)	1.50[n]	0.75
Export elevators[o]		
Unloading (receiving)	1.00	0.50
Loading (shipping)	1.00[p]	0.50
Removal from bins (tunnel belt)	1.40	0.70
Drying	1.05	0.52
Cleaning	3.00	1.50
Headhouse (legs)	1.50	0.75
Tripper (gallery belt)	1.00	0.50

References

a/ Emission factors are in terms of pounds of dust emitted per ton of grain processed by each source.

b/ Emission factor of 1.00 lb/ton for unloading is based on Kansas City elevator study.[1] Table 5 shows the values for truck unloading (0.64) and car unloading (1.30). These data are supported by other data in Reference 2.

c/ The emission factor for loading was taken from the Kansas City elevator study[1] which shows a value of 0.27 lb/ton for car loading (Table 5). Emission factor for truck loading was not determined but is not expected to be significantly different.

d/ Emission factor of 1.40 lb/ton is based on tunnel belt emission factor of 1.40 determined in the Kansas City elevator study (Table 5).[1]

e/ Emission factor of 1.05 lb/ton for drying was based on dryer emissions, discussed in Appendix A of 0.3 lb/ton for column dryers and 1.8 for rack dryers. Other survey data indicate ratio of column to rack dryers at terminal elevators is about 1:1, so an average emission factor of 1.05 lb/ton was used.

f/ An emission factor of 5.78 lb/ton for cleaning of corn is shown in Table 5, whereas data in Table 6 show a much lower value of 0.34 lb/ton for wheat and smaller grains. Therefore, an average value of 3.00 lb/ton was selected. Because the actual emission factor is dependent on the type of grain, it would be more accurate to use the appropriate value for wheat or corn when possible.

g/ An emission factor of 1.5 lb/ton for the headhouse is from the Kansas City elevator study[1] and is shown by Table 5. This value includes garner and scale.

h/ The emission factor for the tripper of 1.00 lb/ton is an estimate based on factors for other sources and observations of tripper emissions.

i/ The emission factor of 0.64 lb/ton for truck unloading was taken from the Kansas City elevator study (Table 5).[1] The value of 0.09 lb/ton shown in Table 6 is lower but was for only one grain (wheat). This is consistent with other data in Reference 1 in which short-term tests showed that the emission factor for unloading of wheat may vary from 0.08 to 1.06 lb/ton.

j/ It was assumed that the emission factor for loading at country elevators would be the same as that for terminal elevators, because no other data was available.

k/ An emission factor of 1.00 lb/ton is based on the average of data for country elevators shown in Table 6.

l/ Emission factor of 0.68 lb/ton for drying at country elevators is discussed in Appendix A which showed 0.3 lb/ton for column dryers and 1.8 lb/ton for rack dryers. Survey data indicated that 75% of dryers at country elevators were column type so an emission factor of 0.68 lb/ton was used.

m/ An emission factor of 6.00 lb/ton for cleaning is based on the Kansas City elevator study[1] which showed a value of 5.78 lb/ton (for corn) in Table 5.

n/ There is a large disparity in the data shown in Table 6 for headhouse (leg) emission factors. However, the average of these data (1.98 lb/ton) is reasonably close to the long-term value of 1.50 lb/ton shown in Table 5.

o/ Emission factors for all sources are assumed to be the same as for terminal elevators, except ship loading.

p/ An emission factor of 1.0 lb/ton for ship loading is based on one test on ship loading at a port elevator in Seattle (EPA Emission Test Report 78-GRN-8).

Meager specific emission test data are available from which uncontrolled emission factors could be computed. Therefore most of the factors for terminal and export elevators are based on results reported in Ref. 1, as summarized in Table 5. Recent EPA test results and some emission test reports from North Dakota (Table 6) were used in deriving emission factors for country elevators. These test reports are short-term emission measurements at a few country elevators, which were compared with the long-term test data for the terminal elevators[1] in order to select emission factors that may be appropriate for country elevators. The emission factor for drying is based mainly on data contained in Refs. 2 and 3, as discussed in Appendix A of this report. All of these emission factors are approximate average values intended to be representative of a variety of grain types but, as noted in Table 4 and in the references, actual emission factors for a specific source could be different, depending on the type of grain (e.g., cleaning) and many other factors.

The emission factors shown in Table 4 represent the amount of dust generated per ton of grain processed through each of the designated operations (i.e., uncontrolled emission factors). Amounts of grain processed through each of these operations in a given elevator are dependent on such factors as the amount of grain turned (interbin transfer), amount dryed, and amount cleaned. Because the amount of grain passing through each operation is often difficult to determine, it may be more useful to express the emission factors in terms of the amount of grain shipped or received, assuming these amounts are about the same over the long term. Emission factors from Table 4 have been modified accordingly and are shown in Table 7 along with the appropriate multiplier that was used as representative of typical ratios of throughput at each operation to the amount of grain shipped or received. This ratio is an approximate value based on average values for turning, cleaning, and drying in each type of elevator, as explained in Table 8. However, operating practices in individual elevators are different, so these ratios, like the basic emission factors themselves, would be more valid for a group of elevators rather than individual elevators.

The factors given in the tables should not be added together in an attempt to obtain a single emission factor value for grain elevators because in most elevators some of the operations are equipped with control devices and some are not. Therefore, any estimation of emissions must be directed to each operation and its associated control device, rather than to the elevator as a whole, unless the purpose was to estimate total potential (i.e., uncontrolled) emissions. An example of the use of emission factors in making an emission inventory is contained in Ref. 3.

Some of the operations listed in the tables, such as the tunnel belt and belt tripper, are internal or in-house dust sources which, if uncontrolled, might show lower than expected atmospheric emissions because of internal settling of dust. The reduction in emissions via internal settling is not known and it is quite possible that all of this dust is eventually emitted to the atmosphere due to subsequent external operations, internal ventilation or other means.

Table 5. BEST AVERAGE VALUE OF LONG-TERM COMPOSITE EMISSION FACTORS FOR A TERMINAL ELEVATOR (LB/TON)[1/]

Operation	Emission factor (lb/ton of grain processed)
Truck unloading	0.64
Car unloading	1.30
Car loading	0.27
Corn cleaner	5.78
Gallery belt	0.11
Tunnel belt	1.40
Headhouse	1.49

Table 6. SUMMARY OF UNCONTROLLED EMISSION FACTOR DATA FROM TESTS AT COUNTRY ELEVATORS

Source	Emission factor (lb/ton) and grain type
Unloading (trucks)	0.09[4/] (wheat)
Removal from bins (tunnel belt hoods and leg boots, etc.)	0.68, 0.37[5/] (wheat) 2.72[5/] (soybeans) 0.91[5/] (corn) 0.63[5/] (milo) 1.06 avg.
Cleaning	0.18[6/] (wheat) 0.40[7/] (not identified) 0.43[8/] (wheat and rye) 0.34 avg.
Headhouse (distributor and legs, but also including dump pits)	0.14[9/] (wheat) 0.10[7/] (not identified) 0.48[8/] (wheat, oats, barley)
(legs only)	1.52[4/] (wheat) 3.47[4/] (milo) 6.15[4/] (soybeans) 1.98 avg.

Table 7. PARTICULATE EMISSION FACTORS FOR GRAIN ELEVATORS BASED ON AMOUNT OF GRAIN RECEIVED OR SHIPPED[a/]

Type of Source	Emission Factor lb/ton processed	x Typical ratio of Tons Processed to Tons Received or Shipped[a,b/]	= Emission Factor lb/ton received or shipped
Terminal Elevators			
Unloading (receiving)	1.00	1.00	1.00
Loading (shipping)	0.27	1.00	0.27
Removal from bins (tunnel belt)	1.40	2.03	2.84
Drying	1.05	0.10	0.11
Cleaning	3.00	0.22	0.66
Headhouse (legs)	1.50	3.03	4.55
Tripper (gallery belt)	1.00	1.71	1.71
Country Elevators			
Unloading (receiving)	0.64	1.00	0.64
Loading (shipping)	0.27	1.00	0.27
Removal from bins	1.00	2.08	2.08
Drying	0.68	0.25	0.17
Cleaning	3.00	0.08	0.24
Headhouse (legs)	1.50	3.08	4.62
Export Elevators			
Unloading (receiving)	1.00	1.00	1.00
Loading (shipping)	1.00	1.00	1.00
Removal from bins (tunnel belt)	1.40	1.23	1.72
Drying	1.05	0.01	0.01
Cleaning	3.00	0.15	0.45
Headhouse (legs)	1.50	2.23	3.35
Tripper (gallery belt)	1.00	1.07	1.07

a/ Assumed that over the long term the amount received is approximately equal to amount shipped.

b/ See Table 8 for explanation of ratios used. These are typical values based on averages taken from a survey of many elevators across the U.S. and can be considerably different for any individual elevators or group of elevators in the same locale.

Table 8. AVERAGE VALUES USED FOR RATIO OF TONS PROCESSED TO TONS SHIPPED OR RECEIVED

Emission Sources	Ratio of Grain Throughput to Grain Received or Shipped for basic elevator functions listed below[a/]												Total[b/]
	Unloading		Loading		Turning		Drying		Cleaning				
Terminal Elevators													
Unloading	1.00										=		1.00
Loading			1.00								=		1.00
Removal from bins			1.00	+	0.71	+	0.10	+	0.22		=		2.03
Drying							0.10				=		0.10
Cleaning									0.22		=		0.22
Headhouse	1.00	+	1.00	+	0.71	+	0.10	+	0.22		=		3.03
Tripper	1.00			+	0.71						=		1.71
Country Elevators													
Unloading	1.00										=		1.00
Loading			1.00								=		1.00
Removal from bins			1.00	+	0.75	+	0.25	+	0.08		=		2.08
Drying							0.25				=		0.25
Cleaning									0.08		=		0.08
Headhouse	1.00	+	1.00	+	0.75	+	0.25	+	0.08		=		3.08
Export Elevators													
Unloading	1.00										=		1.00
Loading			1.00								=		1.00
Removal from bins			1.00	+	0.07	+	0.01	+	0.15		=		1.23
Drying							0.01				=		0.01
Cleaning									0.15		=		0.15
Headhouse	1.00	+	1.00	+	0.07	+	0.01	+	0.15		=		2.23
Tripper	1.00			+	0.07						=		1.07

a/ Values derived from information and data in Reference 3 and are based on a survey of many elevators across the U.S. These ratios may therefore be considerably different for an individual elevator or group of elevators in the same locale.

b/ "Total" represents the overall average ratio of grain throughput to grain received or shipped for each emission source due to all basic elevator functions which involve that source.

As mentioned above, many elevators utilize control devices on at least some sources. In the past, cyclones have commonly been applied to such sources as legs in the headhouse and tunnel belt hooding systems. More recently, fabric filters have been utilized at many elevators on almost all sources. However, some sources in grain elevators do present control problems. Control of load-out operation is one of the more difficult sources to control because of the problem of containment of the emissions. Probably the most difficult source to control, because of the large flow rate and high moisture content of the exhaust gases, is the dryers. Screenhouses or continuously vacuumed screen systems are available for reducing dryer emissions and have been applied at several facilities. Detailed description of dust control systems for grain elevator operations and their estimated costs are contained in Ref. 2.

Grain Processing Operations - Grain processing operations include many of the operations performed in a grain elevator in addition to milling and processing of the grain. Emission factors for different grain milling and processing operations are presented in Table 9. Brief discussions of these different operations and the methods used for arriving at the emission factor values shown in Table 9 are presented below. More detailed discussion and derivation of the emission factors shown in Table 9 are presented in Appendix B.

Emission factor data for feed mill operations are sparse. This is partly due to the fact that many ingredients, whole grain and other dusty materials (bran, dehydrated alfalfa, etc.), are received by both truck and rail and several unloading methods are employed. However, some operations (handling, shipping, and receiving) for a feed mill are similar to operations in a grain elevator, so an emission factor for each of these different operations was estimated on this basis. The remaining operations were estimated from the best information available.[2]

Three emission areas for wheat mill processing operations are grain receiving and handling, cleaning house, and milling operations. Data from a grain elevator study[1] were used to estimate emission factors for grain receiving and handling. Data for the cleaning house were insufficient to estimate an emission factor and information taken from Ref. 2 was used to estimate the emission factor for milling operations. The large emission factor for the milling operation is somewhat misleading because almost all of the sources involved are equipped with control devices to prevent product losses and fabric filters are widely used for this purpose.

Operations for durum mills and rye milling are similar to those of wheat milling. Therefore, most of these emission factors are equal to those for wheat mill operations.

Table 9. PARTICULATE EMISSION FACTORS FOR GRAIN PROCESSING OPERATIONS[a]

Type of source	Emission factors[a,b,c] (uncontrolled except where indicated) (lb/ton)	(kg/MT)
Feed Mills		
Receiving	1.30	0.65
Shipping	0.50	0.25
Handling	3.00	1.50
Grinding	0.10[d]	0.05[d]
Pellet coolers	0.10[d]	0.05[d]
Wheat Mills		
Receiving	1.00	0.50
Precleaning and handling	5.00	2.50
Cleaning house	--	--
Millhouse	70.00	35.00
Durum Mills		
Receiving	1.00	0.50
Precleaning and handling	5.00	2.50
Cleaning house	--	--
Millhouse	--	--
Rye Milling		
Receiving	1.00	0.50
Precleaning and handling	5.00	2.50
Cleaning house	--	--
Millhouse	70.00	35.00
Dry Corn Milling		
Receiving	1.00	0.50
Drying	0.50	0.25
Precleaning and handling	5.00	2.50
Cleaning house	6.00	3.00
Degerming and milling	--	--

Table 9. (Concluded)

Type of source	Emission factors[a,b,d] (uncontrolled except where indicated) (lb/ton)	(kg/MT)
Oat Milling		
Total	2.50[e]	1.25[e]
Rice Milling		
Receiving	0.64	0.32
Handling and precleaning	5.00	2.50
Drying	--	--
Cleaning and millhouse	--	--
Soybean Mills		
Receiving	1.60	0.80
Handling	5.00	2.50
Cleaning	--	--
Drying	7.20	3.60
Cracking and dehulling	3.30	1.65
Hull grinding	2.00	1.00
Bean conditioning	0.10	0.05
Flaking	0.57	0.29
Meal dryer	1.50	0.75
Meal cooler	1.80	0.90
Bulk loading	0.27	0.14
Corn Wet Milling		
Receiving	1.00	0.50
Handling	5.00	2.50
Cleaning	6.00	3.00
Dryers	--	--
Bulk loading	--	--

a/ See Appendix B.
b/ Emission factors are expressed in terms of pounds of dust emitted per ton of grain entering the plant (i.e., received), which is not necessarily the same as the amount of material processed by each operation.
c/ Blanks indicate insufficient information.
d/ Controlled emission factor (controlled with cyclones).
e/ Controlled emission factor (This represents several sources in one plant; some controlled with cyclones and others controlled with fabric filters.)

The grain unloading, handling and cleaning operations for dry corn milling are similar to those in other grain mills but the subsequent operations are somewhat different. Also, some drying of corn received at the mill may be necessary prior to storage. An estimate of the emission factor for drying was obtained from Ref. 2. Insufficient information was available to estimate emission factors for degerming and milling.

Information necessary to estimate emissions from oat milling was unavailable. It was also felt to be unwise to attempt to use emission factor data for other grains because handling of oats is reported to be dustier than many other grains. The only emissions factor data that were available were for controlled emissions.[2] An overall controlled emission factor of 2.5 lb/ton was calculated from this data.

Emission factors for rice milling were based on those for similar operations in other grain handling facilities. Insufficient information was available to estimate emission factors for drying, cleaning and mill house operations.

Information taken from Ref. 2 was used to estimate emission factors for soybean mills.

Information on corn wet-milling emission factors was unavailable in most cases due to the wide variety of products and the diversity of operations. Receiving, handling and cleaning operations emission factors were assumed to be similar to those for dry corn milling.

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APPENDIX A

EMISSION FACTORS FOR GRAIN DRYERS AT GRAIN ELEVATORS

GRAIN DRYER EMISSION FACTORS

A quantitative assessment of emissions from grain dryers is difficult, primarily because of lack of available data. However, these data and other information have indicated that the emission rate from any given installation is dependent upon the dryer configuration, i.e., rack or column; the type of grain being processed, i.e., corn, soybeans, wheat; the foreign material present in the incoming grain, i.e., dust, chaff, "beeswing" hulls, etc.; and the amount of moisture removed which affects throughput.

The large volumes of air passed through the grain, the large cross-sectional area through which the air is exhausted and the wide particle size distribution of the effluent contribute to sampling difficulties. The absence of an acceptable test method makes comparisons between reported dryer emission tests highly uncertain.

A compilation of the available data on emissions test for rack and column type dryers is presented in Table A-1 and, based on these data, average values for the uncontrolled emission factors were selected:

Rack Dryers - 1.8 lb/ton
Column Dryers - 0.3 lb/ton

Because of the small amount of available data, spread in these data, inadequate information regarding specific test methods, use of different sampling trains, and the lack of complete information regarding foreign material and moisture differential, these emission factors should only be considered as indicative of possible average emissions and not absolute numbers for individual dryers.

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Table A-1. SUMMARY OF AVAILABLE EMISSION FACTOR DATA FOR GRAIN DRYERS (UNCONTROLLED)

Rack dryers		Column dryers	
Throughput (bu/hr)	Emission factor (lb/ton)	Throughput (bu/hr)	Emission factor (lb/ton)
1,000	3.7[a]	400	0.23[a]
2,000	2.3[a]	1,000	0.21[a]
500	1.2[b]	3,000	0.6[b]
1,500	0.9[b]		Avg. = 0.3 lb/ton
1,800	1.0[b]		
	Avg. = 1.8 lb/ton		

a/ Reference 2.
b/ Private communication.

APPENDIX B

DERIVATION OF EMISSION FACTORS FOR GRAIN PROCESSING OPERATIONS (as shown in Table 9)

FEED MILLS

Receiving

As stated in Reference 2 (p. 159) the ingredient receiving area represents the most serious dust emission problem in most feed mills. Emission factor data for this operation are sparse, owing partly to the fact that many ingredients; whole grain and other more dusty materials (bran, dehy alfalfa, etc.), are received, by both truck and rail and several unloading methods are employed. For these reasons, an average emission factor would be difficult to determine, at least as far as whole grains are concerned, so an emission factor for the unloading operation only has been estimated as 1.30 lb/ton. This was the value determined in the Kansas City elevator study[1] for car unloading and may be representative of feed mills and hopefully reflects the fact that some ingredients tend to be more dusty than whole grains.

Shipping

Most feed mills ship the bulk feed by truck, but some are also shipped in bags by rail and truck. Reference 2 (p. 166) states that loadout is a major source of dust emissions but little emission factor data are available. An emission factor of 0.27 lb/ton was determined for car loading of grain in the Kansas City elevator study.[1] It is assumed that bulk loading of feed mill products would tend to be more dusty than whole grain loading. Therefore, an emission factor of 0.5 lb/ton has been estimated for this operation.

Handling Operations (transfer points, garner and scale, legs)

No data were available for the internal handling operations in feed mills. However, it would be expected that they are somewhat similar to

those in grain elevators. The Kansas City elevator study[1] showed that the most significant of these operations was the legs, having an emission factor of 1.49 lb/ton. The tunnel belt factor of 1.40 lb/ton is similar but feed mill operations are such that this may not be a comparable operation. However, all material in a feed mill would be expected to pass through a leg at least twice from unloading to shipping. Therefore, an overall average emission factor for feed mill handling operations has been estimated as 3.0 lb/ton.

Grinding

Whole grains received at feed mills must be ground and the associated product recovery cyclone is the major dust source in this grain preparation operation. Because of the wide variation in grains and grinders used, an average emission factor would be difficult to determine. A small amount of data presented in Reference 2 (p. 163) indicated that controlled emissions may range from 0.02 to 0.2 lb/ton. Considering these facts, and lack of other data, an average controlled emission factor of 0.1 lb/ton has been estimated, assuming it is to be representative of the industry as a whole.

Pellet Coolers

The only available emission factor data for this operation was contained in Reference 2 (pp. 164-167) and indicated that the uncontrolled emission factor was quite high (5 to 50 lb/ton) but that the cyclones were very efficient (92 to 99.9%). The data on p. 164 show considerable difference in controlled emission factors for horizontal coolers and column coolers. Distribution of these two types of coolers within the industry is not known but our observations indicate that column coolers are quite common. For this reason, a controlled emission factor of 0.1 lb/ton has been estimated.

WHEAT MILLS

Processing operations were discussed in Reference 2 (p. 207) and identified three emission areas: grain receiving and handling, cleaning house, and milling operations. Emission factors and calculation of emissions for sources within each of these operations is discussed below.

Receiving

It would be expected that receiving of wheat would be similar in emissions to that for terminal grain elevators (0.64 and 1.30 lb/ton).[1] Data on

p. 122 of Reference 2 presents controlled emission factors for fabric filters but it is difficult to use these data in estimating an uncontrolled factor. Therefore, the data from Reference 1 had to be used, and an average factor of 1.0 lb/ton was selected for receiving by trucks, cars, and barges.

Precleaning and Handling

Very little data on uncontrolled emissions from precleaning were available, but it is assumed to consist primarily of scalping type operations, which should be a minor source in comparison with handling operations. Handling consists of legs, transfer points, garner and scale and tripper, etc. Usable data on uncontrolled emission factors for these sources in flour mills were lacking, so the data from Reference 1 had to be used, even though it was for a grain elevator and did not include a tripper. However, it did include a tunnel belt and it is also known that in a flour mill the grain would pass through the leg twice (once when received and once when transferred to cleaning house). Therefore, a cumulative emission factor of 5.0 lb/ton was estimated for all precleaning and handling operations.

Cleaning House

Cleaning is accomplished by a variety of means but often includes air aspiration to remove lighter impurities (dust) as well as disc separators and scourers. Each of these can be a source of dust emissions but only a small amount of emission data on cyclone controlled sources were available in Reference 2 (p. 210). Therefore, it was not feasible to calculate an emission factor for the cleaning house.

Mill House

Operations in the mill house are complex, and again, very little emission data are available. Reference 2 (p. 209) cites one report which indicated that dust generated in roller mills may average 2.1 lb/bu (70 lb/ton). This source and the purifiers might therefore account for more than 70 lb/ton. This emission factor is larger than the one for precleaning and handling and may be erroneously high but it was the only data available. It should be noted that because of the product value these emissions are controlled, primarily with fabric filters.

DURUM MILLS

The sources of air pollution in a durum mill parallel those of a flour mill and fall into the three main categories of receiving and handling operations, cleaning-house, and milling operations. Rate of emission for durum mill operations are limited but since the processing operations are similar to those of a flour mill, the rates are expected to be similar (Reference 2, p. 215). However, in the mill section one of the primary purposes is to produce middlings rather than flour so the break rolls are different. Because of this, it is assumed that the emission factor of 70 lb/ton used for the mill house in flour mills may not be applicable to durum mills. Therefore, the same emission factors for flour mills were assumed to apply, but the emission factor for milling operations was not estimated.

RYE MILLING

The milling procedure for rye consists of the same processing steps as wheat milling (Reference 2, p. 221) and air pollution sources parallel those in a wheat mill. Very little emission factor data were available for rye milling. Some data on certain milling operations (Reference 2, p. 226) indicate a controlled emission factor of about 1 lb/ton. This is equivalent to an uncontrolled emission factor of 10 lb/ton, assuming cyclone efficiencies of 90%. However, these data do not include break rolls and other operations so the factor of 70 lb/ton used for wheat milling was assumed to be applicable to rye. This factor, and the others for wheat milling were assumed to be the same for rye milling.

DRY CORN MILLING

The grain unloading, handling, and cleaning operations are similar to those in other grain mills but the subsequent operations are somewhat different (Reference 2, p. 216). Very little emission factor data were available for dry corn milling, except for some controlled emission factors tabulated in Reference 2 (pp. 222, 223).

Receiving

As in the case of flour mills, an average emission factor of 1.00 lb/ton has been used for the receiving operation.

Drying

Some drying of corn received at the mill may be necessary prior to storage. Types of dryers used (rack or column) is not known, but about 50% use the

Day-Vac system. For this reason, an emission factor of 0.5 lb/ton was used based on dryer emission factors discussed in Appendix A.

Precleaning and Handling

As explained in the section on flour mills, an average emission factor of 5.0 lb/ton was used for the precleaning and handling operations.

Cleaning House

An emission factor of 5.78 lb/ton was determined for a grain elevator corn cleaning operation.[1/] Also, Reference 2 (p. 222) shows an emission factor of 0.0015 lb/bu (0.06 lb/ton) for a cleaning house controlled by a fabric filter. If the FF were 99% efficient, the equivalent uncontrolled factor would be 6.0 lb/ton, which agrees closely with the previous factor of 5.78 lb/ton.

Degerming and Milling

Emission factor data were not available.

OAT MILLING

Most of the information necessary for estimating emission factors was not available. It was felt to be unwise to attempt to use emission factor data for other grains because handling of oats is reported to be dustier than many other grains. The only emission factor data that were available contained controlled emission factors only (Reference 2, p. 236) which can be used to calculate an overall factor of 0.04 lb/bu or 2.5 lb/ton. It is not known if these data, for one mill, included most major dust sources nor is it known if this plant, and the control devices used (cyclones and fabric filters), are representative of the industry. However, both of the above were assumed to be true, and the total controlled emission factor of 2.5 lb/ton was used.

RICE MILLING

Emission factor data for rice milling operations are meager. Emission sources associated with receiving, cleaning and storage are similar to those involved with all grain processing but it is not known if rice emits more or less dust than other grains in these operations. However, emission factors for other grains were used.

Receiving

Data in Reference 2 (p. 471) indicate that most rice is received by truck. An emission factor for truck unloading of 0.64 lb/ton was assumed based on data for a terminal grain elevator.[1/]

Handling and Precleaning

As was explained in the section on wheat mills, a cumulative emission factor of 5.0 lb/ton has been assumed for the similar operations in a rice mill.

Drying

Observation of rice dryers indicates that the emission factor may be considerably higher than for drying of other grains but supporting data were not available.

Cleaning and Mill House

Because of the lack of data, no estimate of the emission factor could be made.

SOYBEAN MILLS

Receiving

Data in Reference 2 (p. 251) indicate an average controlled emission factor for a truck dump pit of 0.017 lb/ton, or an uncontrolled factor of 1.5 lb/ton assuming 99% efficiency for the fabric filter control device. This is in good agreement with data in Reference 1 for soybeans which showed 1.63 lb/ton for truck unloading and 1.51 lb/ton for car unloading. Therefore, an emission factor of 1.6 lb/ton was used for soybean receiving.

Handling

No specific information was available on emission factors for soybean handling operations. Even though the emissions from soybeans may be higher than other grains the cumulative factor of 5.00 lb/ton, as discussed in the wheat milling section, was used.

Cleaning

No information was available on the cleaning of soybeans although it is suggested that it would be at least as much as the 6.00 lb/ton discussed in the section on dry corn milling.

Drying

Soybean plants do dry the feed to the flaking mill and observations have indicated that the emission factor for drying of soybeans at soybean mills may be higher than the average factors discussed in Appendix A. The only data available on soybean dryers are contained in Reference 2 (p. 255) and have been used to calculate uncontrolled emission factors ranging from 4.2 to 80 lb/ton. The value of 80 lb/ton is very high but even disregarding this value, the average factor is 7.2 lb/ton.

Cracking (and dehulling)

Data presented in Reference 2 (p. 256) show that the controlled emission factor for cracking and dehulling operations is on the order of 0.01 lb/bu, or 0.33 lb/ton. If one assumes 90% efficiency for the cyclone control devices, the uncontrolled emission factor would be 3.3 lb/ton.

Hull Grinding

Controlled emission factors for hull grinding in Reference 2 (p. 256) show an average, for three reported values, of 0.0055 lb/bu or 0.18 lb/ton. Again assuming 90% efficiency for the cyclone control devices, the uncontrolled emission factor would be approximately 2.0 lb/ton.

Bean Conditioning

Reference 2 (p. 256) shows a cyclone controlled emission factor of 0.0003 lb/bu or 0.01 lb/ton. Assuming 90% cyclone efficiency, the uncontrolled emission factor is 0.1 lb/ton.

Flaking

A total of four controlled emission factors for flaking are presented in Reference 2 (pp. 252, 256) and show an average of 0.0017 lb/bu or 0.057 lb/ton. These were each cyclone controlled, so assuming 90% efficiency, the uncontrolled emission factor would be 0.57 lb/ton.

Meal Dryer

Cyclone controlled emission factor for meal dryers was presented in Reference 2 (pp. 252, 256) and showed a range of 0.003 to 0.0128 lb/bu with an average of 0.0045 lb/bu or 0.15 lb/ton. Again assuming 90% efficiency for the cyclones, the uncontrolled factor would be 1.5 lb/ton.

Meal Cooler

Only one cyclone controlled emission factor was available (Reference 2, p. 252); 0.0056 lb/bu or 0.18 lb/ton. Assuming 90% efficiency for the cyclone, the uncontrolled factor would be 1.8 lb/ton.

Bulk Loading

No emission factor data were available for meal loading. However, observation of these operations indicates that it may be about the same as loading grain at elevators or about 0.27 lb/ton.[1/]

CORN WET MILLING

Receiving

Corn is received by cars and trucks and, as was done for dry corn mills, an average emission factor of 1.0 lb/ton was used.

Handling

Emission factors specifically applicable to handling of corn at wet corn mills are not available. However, as was done on dry corn mills, an average cumulative emission factor of 5.0 lb/ton was used.

Cleaning

An emission factor of 6.0 lb/ton for corn cleaning, as developed in the section on dry corn mills, was used.

Dryers

Feed, gluten and germ dryers are a major source of emissions from wet corn mills but emission factor data are lacking.

Bulk Loading

Bulk loading of products is another potential source of emissions but no emission factor data are available.